CIM Best Practice Guidelines for Mineral Processing

Foreword

These guidelines were prepared by the Sub-Committee on Best Practice Guidelines for Mineral Processing ('SBPGMP'). The committee reports to the Executive Committee of the Canadian Mineral Processors ('CMP') which is a Technical Society of the Canadian Institute of Mining, Metallurgy, and Petroleum ('CIM') and incorporates those members of the CIM, who are concerned with the processing of mineral ores from mineral deposits. The guideline covers the involvement of mineral processing professionals in providing inputs to the estimation of mineral resources and mineral reserves and providing content to NI 43-101 Technical Reports.

The guidelines consist of 3 documents;

- Principles of Process Support for Mineral Resources/Mineral Reserves Estimation
- Appendix A – Use of Supporting Studies in Process for NI 43-101 Documentation
- Appendix B – Glossary of Terms Used in the Best Practice Guidelines for Mineral Processing

These Best Practice Guidelines for Mineral Processing (BPGMP) supplement the CIM Exploration Best Practices Guidelines and the CIM Estimation of Mineral Resources and Mineral Reserves Best Practice Guidelines (2003) which are referenced in NI 43-101 and recognized internationally. The BPGMP provides guidance specifically for those Qualified Persons (QP) using mineral process information when preparing mineral resource and mineral reserves and preparing supporting documentation under NI 43-101. "*NI 43-101 does not specifically require the qualified person to follow the CIM best practices guidelines. However it is expected that a qualified person acting in compliance with the professional standards of competence and ethics established by their professional association, will generally use procedures and methodologies that are consistent with industry standard practices, as established by CIM or similar organizations in other jurisdictions. Issuers that disclose scientific and technical information that does not conform to industry standard practices could be making misleading disclosure, which is an offence under securities legislation" (from the NI 43-101 Companion Policy).*

The BPGMP deal primarily with the description of best practice as it applies to the mineral processing and extraction of base and precious metal projects. Other commodities may be considered with future updates of these guidelines. These documents indicate those practices which the Qualified Person will consider necessary in preparing their relevant sections to a NI 43-101 Technical Report. It is expected that this a 'living' document and that these guidelines will develop in the future to address the requirements of the mining industry, investing public and mining professionals involved. These guidelines serve to complement, and should be read in conjunction with the CIM Exploration Best Practices Guidelines and the Estimation of Mineral Resource and Mineral Reserve Best Practice Guidelines. Clarifications and changes to these guidelines will be done under the guidance of the Executive Committee of the Canadian Mineral Processors.

The Sub-Committee on Best Practice Guidelines for Mineral Processing (SBPGMP).

At the January 2010 Annual Business Meeting of the National Canadian Mineral Processor's Conference, a general vote of the membership asked the CMP to provide guidelines to the Qualified Persons involved in providing inputs to mineral resource and mineral reserve estimation, and the mineral processing component of NI 43-101 Technical Reports. Changes to NI 43-101 are being considered for implementation by mid 2011 by the Canadian Securities Administrators which is an umbrella organization of Canada's provincial and territorial securities regulators. As a response to the CMP vote, the SBPGMP was established by the CMP Board of Directors and consisted of the following individuals: Chris Fleming, Tony Lipiec, and Larry Urbanoski. The role of this sub-committee is to produce guidelines to provide direction for those persons involved in determining the primary level of processing used to extract value from the mineral project being considered. In particular, the guidelines are for use by those qualified persons requiring input on the key assumptions used in preparing or supervising the preparation of mineral resource and mineral reserve estimates, and the mineral processing and metallurgical testing component of NI 43-101 technical reports.

Principles of Process Support in Mineral Resources/Mineral Reserves Estimation

Principles of Process Support Work

Competence

The key competencies defining the Qualified Person involved in determining process for a particular mineral deposit are their;

- level of education in a field of engineering related to the concentration or extraction of minerals and/or metals,
- general level of experience in the processing of ores,
- prior experience in the concentration or recovery of the mineral or metal being investigated,
- ability to assess the metallurgical work under his or her supervision or that of others being performed to establish the unit operations for use in the extraction of the resource,
- familiarity with the appropriate unit operations used for the extraction of the resource,
- familiarity with the commodity (or commodities) and the impact of deleterious elements,
- familiarity with the economics of that segment of the industry, and
- experience with the metallurgy associated with the style of mineralization and basic mineralogy being considered.

This is critical in determining that the right individual(s) is providing the metallurgical inputs for mineral resource and mineral reserve estimation of the deposit being examined. As a general guide, a person being called upon to act as Qualified Person should be clearly satisfied in their own mind that they could face their peers and demonstrate competence in the commodity, metallurgical characteristics, process methods and situation under consideration. If doubt exists, the person should either seek opinions from appropriately experienced colleagues or should decline to act as a QP for that circumstance. The QP responsible for determining the process must understand the significance of each discipline's contribution to the reliability of the process design and assessment of economic viability. While supervising QPs do not need to be experts in all aspects of the work they supervise, they should be sufficiently knowledgeable about the information for which they are accepting responsibility. They must perform a level of due diligence in those areas of work to an objective level of reasonableness that their peers would accept.

The need for input from a QP increases the higher the level of confidence of mineral resource/reserve category being estimated. Depending on the type of mineral deposit, input from a QP may be required even at early stages of work on the deposit.

Increasing the Level of Process Confidence

The role of the QP is to estimate the process response variability of a mineral deposit and the risk to recovery of a saleable product at a given economic production cost to a level appropriate to support the determination of appropriate cut-off grade of the mineral resource and the confidence categories of mineral resource or mineral reserve being estimated for the mineral project. This information is as critical as the geological and geochemical grade continuity which is determined by geologists and assayers through the use of drilling and other exploration techniques.

As the confidence level of the mineral resource increases with more data gathered by geological techniques including drilling and assaying, the quality of the supporting process information should also increase. This information is produced by;

- geometallurgical logging and domaining of the deposit,
- testing of samples for recovery, product quality, and physical characteristics,
- interpretation of testwork,
- modelling of testwork information,
- process definition,
- design engineering,
- capital cost estimating, and
- operating cost estimating.

Increasing the confidence categories of the mineral resources and mineral reserves requires an increased level of understanding of each type of information used to support the key assumptions in the estimate.

The purpose of this Best Practice Guideline for Mineral Processing is to assist the process engineer acting as the QP in considering all of the factors that determine the continuity of metallurgical recovery. Rather than providing a prescriptive checklist, it is expected that a QP will use his or her judgment in determining the level of work required to support the resource classification in question. As deposits increase in size, decrease in grade, and increase in complexity, the QP ensures that the appropriate amount of effort has been used in defining the process response of the material at the level of variability considered in the mineral resource or reserve estimates.

Supporting the Definition of the Process

The establishment of the conceptual treatment process for any deposit should include:

- the identification of the mineral beneficiation method that would allow the production of a saleable concentrate or
- the identification of a metal extraction method allowing the production of a bullion or finished metal product (e.g. the production of cathode copper from a heap leach operation) and
- characterization of the tailings being produced for disposal

The definition of the process needs to incorporate a logical chain of unit operations necessary to produce the saleable product and prepare the tailings for suitable disposal. The level of definition will vary with the size, complexity, and stage of development of the mineral resource/mineral reserve being examined. The level of definition must be appropriate to the confidence categories of mineral resources or mineral reserves being supported and the current stage of project development. This level of definition is supported by the work indicated in the Design Definition Process as described in Appendix A. This appendix provides an outline of the key parameters that should be established by testwork to evaluate the level of technical risk, and costs associated with the selected process method.

In very preliminary mineral resource reports there may not be a QP specifically for process. The QP preparing the mineral resource estimate should seek the advice of a mineral processing specialist after these initial estimation stages. As the deposit evaluation progresses and the level of confidence in the mineral resource categories increase, a QP qualified in process

development should provide input on the process information necessary to support the resource definition.

Sample Selection

The most important concept behind sample selection and collection is that it should be similar to the role played by drilling density in establishing geological and grade continuity. The number of samples collected from a given volume of resource to be processed, and their use in the supporting testwork confirming the classification of the mineral resources, should increase at a level appropriate to the mineral resource or reserve classification category being supported.

Sample selection should take into account;

- the stage of development of the project and the confidence level of the mineral resource or reserve categories being supported,
- the geological complexity of the project,
- the complexity of the process route, and
- the size of the samples appropriate to carry out the testwork.

The selection of samples must be from within the area of the mineral resource estimate, and should represent all of the major geological and mineralogical ore domains. The extent of sampling is dependent on the expected confidence level of mineral resource/mineral reserve definition, but should have a spatial density and range appropriate to the size and complexity of the deposit. Samples should not only include those areas of mineralization expected as being of the average grade within the deposit, but should include material approaching cut-off grade levels where mineral resource definition is evaluating higher confidence categories. In addition, the impact of mineralogically problematic material and/or gangue minerals resulting from dilution of mineralization should be considered in the selection of samples.

The sampling protocol used and the results of the sampling for metallurgical purposes must be verified by the QP. The QP should establish with the other QPs (geology. mining, etc.) how representative the metallurgical samples are of the expected mill feed. Selection of the samples should be appropriate for the intended testing purpose and take into account the mining of the deposit. Any potential biases within the samples that could affect metallurgical testwork should be identified and methods for ameliorating these biases should be undertaken. To reduce project risk, the samples selected should emphasize those parts of the deposit critical to the early years of production, which usually have the most significant impact on the economics.

The potential effect of storage time, conditions, and transportation on the quality of the metallurgical samples should be considered when appraising whether the samples are appropriate for process testwork.

Testing of Samples

Testwork is the use of industry-accepted scientific procedures to determine the preparation and separation/extraction characteristics of the mineralization of economic interest within the deposit. It is essential that testing represent a balanced approach to the majority of the deposit and not concentrate work on only a small portion of the deposit. The goal of the testwork is to establish the continuity of mineral or metal recovery, together with the ability to safely produce a saleable product and to characterize the tailings to be disposed.

The number of samples tested and the confidence level of parameter definition vary with the complexity of the mineralization, the complexity of the expected process route, and the expected confidence categories of mineral resources/mineral reserves to be determined. The nature and style of both mineralization and gangue material should be considered to determine their impact on process and recovery. These influences include but are not limited to:

- mineral species,
- mineral compositions,
- grain size and morphology
- grain texture, and
- mineral associations.

The level of detail in the investigation must increase as the project advances through the various stages of development.

During the early stages of mineral project evaluation conceptual process development may be based on similar deposits. The QP should judge whether it is appropriate to use broad composite or point samples for preliminary metallurgical testwork. During this work, process alternatives are examined and considered with the goal of selecting a recovery/extraction method most suitable for the orebody. With the development of a suitable mineral processing method that is suitable in cost and valuable mineral recovery, it is necessary to test the method with variability samples to explore the impact of spatial and domain mineralization variability at the prefeasibility and feasibility level of study used to support the categorization of the resources. The complexity and novelty of the selected process flowsheet will also drive the level of work necessary to investigate performance and interaction between unit operations. The influence of gangue minerals, contaminants and impurities should be investigated in greater detail as the level of the project advances.

The quantity of testwork supporting the results at the various stages of project development should be indicated together with the level of confidence achieved in these results. Early work (especially when there is limited sample available) or work from small scale projects may be limited in scope. In general, the quantity and quality of testwork will increase during more advanced studies. This especially applies to large and complex mineral deposits where the process is being applied at the lowest possible cut-off grade to maximize the quantity of the resource or when novel technology is required to develop an economically viable project. The QP plays an important role in providing recovery values, capital and operating costs and the review of smelter terms supplied for cut-off grade determination by the geological modelling and must make all assumptions and sensitivities clear. Where different cut-off grades are provided (e.g. for ores to be sent to heap leaching instead of milling) these must be separately identified and provided.

Testwork needs to include aspects of quality assurance and control appropriate to the level of reserve definition. Control is through the examination of assay and metallurgical laboratory and audit procedures results, and adherence to standard or industry-accepted operating procedures. The quality of the laboratory should be verified by the QP and, in the case of complex or novel processes, the QP should visit the facility performing the work. In the case of complex testwork, novel processes, or where the number of samples is limited, or where work has occurred in the past by reputable groups, the QP must ensure that audit procedures involve the use of internal or external peer reviews of this critical work.

An important measure of testwork quality is the QP's assessment of the degree to which all the test results are consistent and verifiable. If the suite of testing results does not point to a coherent process design, then it must be concluded that the metallurgical characteristics of the material are not properly understood, and additional or repeat sampling and testing are indicated to be necessary.

Within the NI 43-101 Technical Report, the identification and description of the various test programs is summarized and the relevant results explained. In addition, there should be a review and evaluation that the analytical methods used to establish sample grades, material characteristics and final product quality are appropriate to the material.

Essential Components of the Process Support in the Technical Report

Support of the Process Design by the Sampling & Testing

Initially, the mineralogical and physical characterization of samples is used to define a potential processing route in early appraisal of the deposit. This processing route is then confirmed by testwork used to establish the response of the mineralization.

The level of the testwork must be appropriate to the level of study supporting the categorization of the resource. It is the responsibility of the QP to determine if the interpretation of the testwork explains the metallurgical response in a satisfactory manner and to an appropriate level of detail, consistency and confidence. The QP will establish Process Design Criteria ('PDC') which are a critical part of the document outlining the key parameters of the process design. The process design should be appropriate for the size, variability and mineralogy of the deposit. The PDC will typically include the following factors;

- design factors (availability, etc.)
- product recoveries
- product quality (grade, deleterious elements, etc.)
- metallurgical balance (including throughput, %solids, etc.)
- hardness (grindability)
- particle sizes and densities being used in the unit operations
- specific gravity
- bulk density
- presence and distribution of the deleterious elements within concentrate and tailings
- process selection

In determining the information which goes into the PDC, the qualified person may have applied discounts or modifications to the information presented in the PDC. It is expected that the appropriate use of discounts are at the discretion of the QP based on experience and the stage of the project.

The design document supporting the studies is indicated in Appendix A but critical in determining the economic impact of the design will be the economic deliverables indicating;

- capital cost
- operating cost
- sustaining capital cost

Within the NI 43-101 Technical Report, the metallurgy confirms the continuity of recovery at given process parameters throughout the mineral resource/mineral reserve. The QP contributes to the parameters supporting calculation of cut-off grades, and thus directly contributes to meeting the definition of confidence categories within the mineral resource/mineral reserve model.

Where non-commercialized technology is being used within the process plant definition, it is necessary to provide proof of concept at the preliminary economic assessment (scoping study) level, proof of economic and technical viability at the prefeasibility level, and proof of applicability at the feasibility level. The NI 43-101 Technical Report should clearly inform the reader of the risks associated with any of the considered technologies and in particular with those technologies that are not proven.

It is expected that the process design will not only take into account economic factors but will also address worker health and safety in the process facilities to an appropriate level. The design must also reasonably deal with the production of any odious and toxic emissions produced by the process facilities. The QP in process will also be involved in the characterization of the process tailings being disposed. At early stages of property work, the QP may provide some guidance as to the appropriate disposal of tailings, however as the level of reserve category is increased the level of work involved in the disposal of wastes, tailings and control of emissions will increase. It is expected that at a minimum, experts will be involved in the prefeasibility study and at the feasibility study and operations level, there will be a suitably qualified QP specifically guiding environmental issues.

Role of Capital Cost Estimating

The role of a capital cost estimate is to provide an estimate of the process plant cost necessary to achieve the recovery, the product quality, and preparation of tailings for disposal that was used in the definition of the mineral resources/mineral reserves.

The cost estimate of the processing plant and other required facilities should be appropriate to;

- the selected process at the selected process rate,
- the project geography,
- topography,
- seismicity
- availability and usage of water,
- climate,
- logistics, and
- region-specific factors such as the availability of skilled tradesmen, etc.

The QP will judge which factors are influential in the costing of the process plant and that these have been addressed. There needs to be an indication of how the costs are developed and to what level of definition and accuracy (see Appendix A). Given that there are differences in these levels of definition and accuracy, it is expected that an adequate contingency appropriate to the level of the supporting study is provided. This contingency provides costs to cover the risk of potential but uncertain cost increases on direct and indirect costs. It is expected that in advanced studies, especially of large and complex projects, that the QPs will be supported by expert cost estimators. The QP reviews and takes responsibility for costs done within the

process area. This requires the QP to perform due diligence to the Objective Standard of Reasonableness as defined by NI 43-101.

Role of Operating Cost

The role of an operating cost estimate is to provide an estimate of the process plant cost necessary to achieve the recovery and product quality that was used in the definition of the mineral resources/mineral reserves.

The factors typically contributing to the operating cost include;

- media and liner consumption in comminution,
- reagent usage and cost,
- maintenance consumables and cost,
- staff and labour costs,
- transportation costs,
- tailings disposal,
- spare parts and maintenance supplies, and
- power usage and costs

Operating cost estimation activities should be appropriate to the level of the study (see Appendix A) forming the basis of the mineral resource/mineral reserve estimation (see Appendix A). The level of estimate support should be defined by the QP. As the level of study progresses, the variable response of the plant to mineralization, hardness and other metallurgical parameters such as flotation and/or leaching response should be accounted for in the financial analysis, in particular when converting the estimated mineral resources to mineral reserves. The impact of location in determining the supply of skilled human resources on the appropriate schedule, consumables and spare parts to the mine site or mineral products from the mine site to market should be indicated, especially if transportation is considered to be a potentially complex undertaking. Also of critical importance to process is the determination of water and power availability and cost. This especially applies to the processing of large low-grade deposits or complex projects in remote locations. It is expected that in advanced studies, especially of large and complex projects, that the QPs will be supported by expert cost estimators. The QP in process reviews and takes responsibility for costs estimated within the process area. This requires the QP to perform a due diligence to the Objective Standard of Reasonableness as defined by NI 43-101.

Off-Site Treatment of Product

One of the significant costs attributable to process is that of the off-site treatment of the product generated at the minesite. In the case of both concentrates and extracted metal or bullion, this should include transportation, marketing and insurance costs. In the case of concentrates or other intermediate metal products, the cost of producing a saleable product by smelting or hydrometallurgical treatment should be included. In addition to these costs, factors such as the presence of penalty elements or the sensitivity of the smelter to concentrate purity and grade should be indicated. The impact of location in determining the ease of shipping the process products should be assessed, and whether this is logistically complex or impeded by seasonal weather or other factors.

As these treatment costs are included within the parameters provided to the determination of the resources and reserves, it is necessary for the QP to provide a judgment as to the impact to

cost and whether there is a risk in marketing the end product as to quantity supplied into the market or quality. If the quantity or quality is unusual, this needs to be commented on. Any relationship between the project and proposed end user may require comment. While the QP may determine the marketability for the end products in early studies, it is expected that experts will be used at higher levels of study.

Use of Experts

The QP in process is likely to have to consider areas where the assistance of experts may be required to more fully define those areas. These include project execution and constructability, logistical capability, infrastructure support, environmental factors, local weather, topography and geography, marketing, and the community response to the type of processing facility being envisaged. In these cases, especially at advanced project levels, the QP is expected to rely on the work of other experts especially where the QP must provide an opinion that extends the bounds of their direct experience. If the QP is taking responsibility for the assessment of these sections, it is the duty of the QP to conduct sufficient due diligence to be assured that the expert has the required background and training to complete the task and to explain the result to the QP. The QP is then required to take responsibility for the work. It is expected that the QP will indicate the level of infrastructure required in terms of transportation, power and water to operate the plant and whether this has been considered in the study, and to what level.

Providing Recommendations

For early stage projects, and to provide support for estimation of mineral resources, the QP is expected to provide a preliminary estimate of the costs and time required to establish the more detailed work including risk reduction required for the next step of deposit and project development. Further, the QP will indicate opportunities and risks, and how information should be developed to address those issues pertinent to process in the continuing assessment of the project. These are typically included in the recommendations section of the Technical Report, and must include an estimation of the time required to complete the work, and a reasonable budget figure for completion.

Risk

Risk should be considered by the QP when agreeing to the confidence categories (used in the Technical Report), the level of study, the testwork and process design supports. The QP in process should pay particular attention to providing indications of process risk in the Technical Report. This risk may arise from inadequate sampling, inadequate process development or from the complexity of the ore. The QP should further indicate those approaches used in the report to mitigate these various risks. Where the risk is considered to have serious negative impact upon the economics of the project, this risk must be identified as well as the likelihood of occurrence. Serious risk may result in the level of mineral resource or reserve confidence category being downgraded despite the level of confidence in the geological and grade continuity and may cause the confidence category to be decreased.

The QP should also, at the reserve category, identify any potential for risk not only in long term continuous production but also in initial production and metallurgical ramp-up schedules resulting from the lack of qualified personal and/or supplies or services, or the supply of inappropriate feed to the plant.

Where cautionary statements or contingency are used due to gaps in knowledge produced by lack of sampling, testing, and engineering definitions, the assumptions used to bridge these gaps should be based on similar deposits.

Transparency of Language

The use of clear language and detail is to ensure that the QP's work within the report discloses all of the material factors affecting the design and application of a process to the resource for the production of a saleable product. The reader of the Technical Report should be provided with sufficient information presented in a clear and unambiguous way.

At an early stage of project development, there may be relatively little process information available. What is available should be presented, and be accompanied by a discussion of the risks imposed by the limited information. As more detailed information becomes available, the sensitivity of the process plant design to fluctuations in throughput, recovery and product quality should be indicated.

Attention should be paid to the presentation of information. All information that is materially important in defining the level of process response should be presented unambiguously and must not be misleading. Where problems in process are expected, steps that have been taken to mitigate the risk should be indicated. For example, it should be acknowledged when recovery values and product quality differ between tests within the completed testing programs, even at early stages of project development. Adjusted recoveries and product qualities need to be explained and risks identified and discussed where appropriate. Particle size is another critical area where the levels used in testing and design are identified and related.

In addition to the discussion of process response , the QP should consider including a section on Process Mineralogy to elaborate on all those mineralogical factors which could influence metallurgical response including;

- deleterious elements,
- fragmentation characteristics, and
- mineral grain size, complexity, distribution and ratios.

Comparison with existing operations treating ores of similar mineralogy would be of benefit to the reader.

It is expected that the QP will indicate for life of mine (including the potential level of variance and its impact);

- recovery of the valuable material,
- quality of the final product (including impurities and deleterious elements) sold to an end user, and
- throughput.

Within the report, the QP should include at minimum a simplified process flowsheet beginning with ore arrival to the process and ending at shipment of the end product off site and the discharge of tailings to the tailings facilities. Apart from the most preliminary level work, there should be a site plan indicating the location of the process and tailings management facilities relative to mining and also infrastructure. Wherever possible, data should be explained through the use of tables.

Where it has not been possible to develop the support to a level normally applicable to the classification level of the mineral resource as judged by the QP, it is necessary to indicate within a Technical Report that such a risk exists and discuss its potential impact upon the classification of the resource.

The use of clear language is not limited to the Technical Report but also applies to those press releases being approved by the QP ~~for Process~~, which represent their work. It is important that the presentation of the information in the press release is consistent with the content of the original Technical Report. In the same manner that tonnages and grades are directly related during mineral resource and mineral reserve estimation, for the QP, the percentage recovery is directly related to an associated product quality and that should be made clear in the reporting document. The QP performing the process work should be reminded that the same considerations regarding significant figures and terminology that should be applied to mineral resource and mineral/ore reserve estimates should also be applied to the other information presented in a technical report.

General

The QP should use peer review by other suitably qualified persons in ascertaining if the detail included in their work is appropriate to support the classification level of mineral resources/mineral reserves and that it meets the definitions as defined within NI 43-101. The QP should be aware of the level of support that is currently considered to be industry leading practice for the level of study that they are using to support the classification of the estimates.